

Twin Paradox Project Update Including the Mainstream Response

J. N. Percival

79 Haviland Road, Ridgefield, CT 06877-2810

e-mail: NPercival@SNET.net

A brief discussion of the "Open Letter on the Twin Paradox" and the other 10 supporting pages in the web site are described. A summary of the findings of the associated study report is given. Special attention is focused on the mainstream response.

1. Open Letter to the Physics Community: The Twin Paradox

As the first step in the Twin Paradox Project, an Open Letter to the physics community was posted on the internet in October 2010 [1]. The Open Letter noted the wide range of conflicting solutions to the Twin Paradox that were published in top physics journals and textbooks and taught in college/university physics classes. The Open Letter called for a cooperative effort to resolve these conflicting views.

2. Report

A Report page was added to the Open Letter website giving background information on the Twin Paradox debate. The Report enumerated 21 classes of solutions that had been published in physics journals. The Report noted that velocity dependent, clock slowing data was asymmetric rather than symmetric as Special Relativity predicts and requires a construct outside of currently accepted physics, namely, a special physics frame where velocity with respect to that frame causes clocks to slow.

3. Analysis of Proposed Mainstream Solutions

Several pages of the website reviewed the most widely accepted categories of published mainstream solutions trying to reconcile the paradox with currently accepted theory. It was shown that all such solutions lead to multiple, obvious contradictions.

4. Mainstream Response to the Open Letter

The project sent out emails and letters to the physics community including universities, journals and professors asking for their input and included a questionnaire such as is shown on the "Survey Questionnaire" web page. Initially, there was no response. This may have been due to many in the mainstream reacting to the topic of the Twin Paradox dismissively and tending to think those who raise the topic are "quacks". Hence, a little background may provide some balance.

A review of the Twin Paradox literature [1, [References section](#)] shows a repeating cycle. The first cycle began with Einstein's 1905 paper claiming a special relativity solution to how a net proper time difference would accumulate between a "stay-at-home clock" and a clock that made a round trip. Then critics pointed out contradictions in that specific solution. The critics were scoffed at and, in essence, labeled as "quacks". Eventually,

that specific solution faded from favor, because of the contradictions pointed out by the critics, and another specific solution gained popularity. Einstein's original, now displaced solution was not explicitly discarded and the critics were not congratulated for their contribution to moving the debate forward, but continued to be scoffed at and labeled as "quacks". Then the cycle repeats with the newly crowned solution. There have been four major cycles (Einstein's original time dilation claim, Minkowski diagrams and/or invariance of the interval, virtual gravitational field, relative simultaneity) and 17 additional minor cycles (see section "3) Accepted Resolutions" of the Report web page.

4.1. Response Overview

We received 5 responses to our inquiries on the Twin Paradox claiming there is no paradox. On the other hand, to date (4/16/12), we have collected 140 signatures to the Twin Paradox Open Letter indicating agreement that the Twin Paradox has not been satisfactorily or clearly reconciled with currently accepted theory - many of those signatures coming from professors who would be considered "mainstream", at least had they not voiced such views.

The 5 dissenting responses seem to agree that current theory cannot describe the how, when, where of the net proper time difference (NPTD) accumulation. So that leaves the question, "Is the physics of NPTD accumulation *inherently* unknowable?" or just "unknowable *in the context of currently accepted theory*". Since pre-Einstein Relativity physics straightforwardly explains the detailed physics of the NPTD, we suggest it's the latter case and currently accepted theory lacks the special physics frame construct required to understand the Twin Paradox and several other physics phenomena.

To questions addressing, "How does the net proper time difference (NPTD) accumulate?", the mainstream responders answered, in effect, that one could not know. This is a significant change from the series of specific answers discussed above. Their reasoning for this new agnosticism, aside from the failure of previous attempts at being specific, is as follows.

Proper time is the time that accumulates on an observer's time piece between two events on his worldline. That value is well defined and invariant (i.e., observer independent). The net proper time difference (NPTD) *for the total round trip* is well defined because the start and end events are on the worldlines of both twins - in other words, the twins share the start event and end events so reading the clocks for each of those events is simultaneous for the twins - they are not separated so there's no issue of

what time for the traveling twin is simultaneous with what time for the traveling twin.

Conversely, when A and B are physically separated, one cannot use *relativity* to determine a net proper time difference between A and B *because of relative simultaneity* – i.e., using *relativity* when A and B are separated, one cannot tell, which events on A's worldline are simultaneous with which events on B's worldline because observers in different frames have different views on which events are simultaneous with other events. This *relativity based argument* continues that if one cannot determine the net proper time difference (NPTD) between A and B, when A and B are physically separated, then one cannot describe or give a physical description of how the proper time difference accumulates. So this "we don't know" argument would seem to save the day for the mainstream's goal of reconciling how the Twin Paradox NPTD accumulates with currently accepted theory. However, the "we don't know" argument has the same problem as previous reconciliation arguments as it mixes proper time with observed time (relative simultaneity).

Simple logic shows that the proper time difference must accumulate in a specific way and this is confirmed by GPS. In GPS, clocks in satellites have their clock rate adjusted to zero out the effect that their velocity would have on slowing their clocks (The clock rate is also adjusted to zero out the effect of a difference in gravitational potential, but that's a separate topic.) So it's clear that if the clock rates did not have this velocity effect adjustment, just the gravitational potential adjustment, that the satellite clocks would continuously "lose" time as a function of a difference between the "slowed" satellite clock rate and the earth clock rate. This difference in rate would be as smooth as the velocity is smooth. This shows that the proper time difference accumulates smoothly as a function of velocity. It also shows that, unlike Special Relativity's symmetric time dilation, this very physical effect of an accumulating proper time difference is asymmetric – in other words, the earth clocks would be accumulating a positive proper time difference while the satellite clocks would be accumulating a negative proper time difference. This asymmetry cannot be explained away using the bogus contention that was temporarily raised to save Einstein's original claim. That contention was that one can only use Special Relativity's construct of relative velocity to compute the difference from the stay-at-home frame perspective because the travelling twin accelerated. This contention was seen at the time to be clearly fallacious and just a desperate attempt to save Einstein's claim. For GPS, that contention can't even be raised as both the earth clocks and the satellite clocks are accelerating. Thus, not only logic but mountains of data show that the proper time difference accumulates in a specific way, namely, by clock retardation as a function of velocity and that the proper time difference is NOT due to symmetric relative velocity. This should be obvious to any physicist, but the reason it is not currently accepted is due to one thing – the conclusion is not consistent with currently accepted theory.

Below we give the 2 dissenting responses that went beyond just answering the survey questions and comment on them.

4.2. Mainstream Response: Detail

Responder #1: We sincerely thank Professor Gerard 't Hooft, Nobel Laureate and current Editor of *Foundations of Physics*, for

responding to our inquiries. It should be noted that Special Relativity and the Twin Paradox are not directly related to Prof. 't Hooft's primary research activities and that further he most likely thinks that the Twin Paradox is a dead issue, hence, was in a somewhat dismissive mindset and further was busy with most demanding jobs – however, note that many/most physics professors would fit into similar molds.

Percival: We started by directing Prof. 't Hooft to the original Open Letter and asking if he could make readers of *Foundations of Physics* aware of that letter by providing a pointer (URL) to it and further asked:

"If not, please let us know if:

- 1) you feel the Twin Paradox is a dead issue. If so, please let us know what you consider THE reconciliation argument (e.g., "SR time dilation"). Getting such feedback is part of our ongoing study. OR
- 2) you hold that the Twin Paradox is an unresolved issue that requires more analysis."

Prof. 't Hooft: "There is no difficulty of any kind with the twin paradox; it was basically resolved with Einstein's 1916 theory. Details of the resolution depend on what exactly people think the problem is, but one generally concludes that, once the theory is sufficiently carefully formulated, there's no contradiction of any sort left anywhere.

There exist unresolved issues in physics, but if at all they are only remotely related to the twin paradox."

Percival: The main point in our reply was: "If there was general consensus that Einstein's 1916 paper was THE answer, then the Open Letter would not have been written. The point of the Open Letter, made in some depth, is that there's nothing approaching such a consensus on any solution, but rather a broad range of mutually exclusive solutions."

Prof. 't Hooft: "I won't support such an "open letter" because it contains nonsense. If you perceive the explanations in the popular literature as "contradictory" and "mutually exclusive" it is because undoubtedly different authors have different perceptions about what actually the problem is. Whatever people perceive as a problem can be explained and resolved, where Einstein's 1916 paper plays an essential role. In the professional literature the "paradox" or the "problem" hardly receives any attention at all because there is no paradox anymore, and no problem. Only in circles of outsiders and laymen scientists, apparently, some discussion may be lingering. The topic is rarely touched upon even in a journal such as *Foundations of Physics*, where we do sometimes accept papers where rather trivial long-resolved issues are mentioned."

[Note on the above: The last three sentences confirm what many complain about, namely, regardless of motive, there is a de facto bias against publishing material that rebuts arguments reconciling the Twin Paradox with currently accepted theory. Also, we did not raise any problems, but just asked for the solution – if that solution were straightforward, then a straightforward, unambiguous answer should have been forthcoming.]

Percival: The main point in our reply was: "Your email below gave your response [i.e., Einstein's 1916 paper provides the answer]. However, I thought that there were two ways one could

interpret your response. Hence, I asked some colleagues for clarification and got back those two different interpretations. Could you please select the one below that represents your response or provide your own clarification.

- 1) The 1916 General Relativity View - A space-time diagram of the round trip is drawn using the rest frame of the stay-at-home twin. The invariance of the interval is used to show that the proper time for the traveling twin is less than for the stay-at-home twin by the standard factor. For a classic Twin Paradox scenario, one half the net proper time difference accumulates in the outbound segment and one half in the inbound segment. The net proper time difference is seen to accumulate smoothly during the constant velocity segments.
- 2) The General Relativity Explanation - The turnaround acceleration creates an (artificial/virtual) gravitational field and the difference in gravitational potential between the accelerating twin and the stay-at-home twin causes the net proper time difference. The net proper time difference accumulates during the turnaround acceleration."

Prof. 't Hooft: "Indeed, as I said in my previous answer, the resolution to the problem depends on what you think the problem is. To me, and most other modern scientists, there is no problem at all, so to provide an answer is somewhat tricky / if I give an answer the response might be: "O, but that wasn't my problem ..."

So, answer # 1 applies if your problem is: "How do we calculate the age difference between the two twin brothers?". The answer is given, plain and simple.

Answer # 2 responds to the next question: "Yes, but the result of this calculation worries us. How come that I can't do the calculation using the frame of the travelling brother? Then the result would seem to be the opposite - the brother who would stay at home on Earth would seem to become the younger one!"

Expanding on the answer already given: the calculation under 1 is only allowed in non-accelerating frames; the frame of the travelling brother has to undergo accelerations, so it cannot be used at all times. Thus, there is an asymmetry. If you want to use the frame of the travelling brother, special relativity has to be replaced by general relativity, where accelerating frames ARE allowed. Here, however, one necessarily also encounters gravitational fields. So, in the accelerating frame of the travelling brother, a strong "artificial" gravitational field during his acceleration accelerates and slows down clocks in such a way that the two calculations now agree: the travelling brother will stay younger, according to BOTH calculations.

Then your next question might be: "Yes, but how come that the two clocks peed up or slow down at different moments in the two calculations?" Answer (#3): that's no contradiction; clocks can only be compared directly when they are close to each other; when they are far apart their relative speeds depend on how you define simultaneity".

I don't know what the next question would be, but again, there is no contradiction anywhere."

[Note on the above: Actually, we did not pose any problems, but rather just asked for THE solution.]

Percival: In our reply, we sent an early, but quite similar version of the questionnaire shown on the Survey Questionnaire page.

Prof. 't Hooft: "These questions cannot be answered by YES or NO, but all of them deserve the answer: THIS IS ... AND ILL-DEFINED QUESTION. The NPTD depends on how simultaneity is defined."

[Note on the above: The view that asking about how the NPTD accumulates is an ill defined question means that the answer is that currently accepted theory claims that one cannot tell how the NPTD accumulates.]

Percival: That point is seconded by the assertion that "The NPTD depends on how simultaneity is defined." We, at the NPA, agree that, in the context of relativity theory, that's a 100% accurate answer! However, we would NOT agree with any implication that how the NPTD accumulates is *inherently* unknowable. Also, we do not agree with the assertion that "The NPTD [when the twins are separated] depends on how simultaneity is defined" is valid. It's true that what an observer *calculates* the NPTD to be, using relative velocities, when the twins are separated, is indeed dependent on how simultaneity is defined. However, proper time for each twin is an invariant. Proper time accumulates at a specific rate for each twin between each pair of events. For the stay-at-home twin proper time accumulates at a single rate for the whole Twin Paradox scenario. For the "travelling" twin, proper time accumulates at a single rate between the key events (e.g., start and end of a constant velocity segment). Hence, the proper time difference accumulated between key events on the travelling twin's worldline is easily calculated. Pre-Einstein Relativity physics straightforwardly describes how the NPTD accumulates and this description is consistent with all relevant data. Furthermore, any argument that how the NPTD accumulates is unknown or differs from this straightforward explanation has been equally straightforwardly rebutted. In summary, we agree that indeed in the context of currently accepted theory, one cannot tell how the NPTD accumulates and this is a limitation of currently accepted theory. Understanding how the NPTD accumulates requires a special physics frame construct and clock retardation as a function of velocity with respect to that special frame. We did ask for further clarification and specifics, but Prof. 't Hooft declined, understandably - given mindset and primary focus, thinking that he had covered the topic. We again thank Prof. 't Hooft for taking the time to respond to our inquiries.

The only part of Prof. 't Hooft's answer that seemed disingenuous was his not being able to say "Yes" or "No" to whether a full range of specific, mutually exclusive physical cases (e.g., time dilation, relative simultaneity, gravitational fields) produced the NPTD so we thank Prof. 't Hooft for his overall candor.

Responder #2: We sincerely thank Professor Hermann Nicolai, Director of the Albert Einstein Institute (AEI), which the German government has declared to be the official spokesperson for relativity. Hence, it should be noted that Professor Hermann Nicolai would, quite properly, feel it his professional duty to defend relativity.

Percival: In response to an initial inquiry from a German NPA member, Prof. Hermann Nicolai had referenced a Minkowski diagram and given the formula for proper time. Trying to get specifics, we asked,

- 1) If his invocation of Minkowski diagrams implied that the NPTD accumulates smoothly during the constant velocity segments?
- 2) If half the NPTD accumulates during the outbound segment and half during the inbound segment?; 3) What is the physical cause of this physical effect? 4) Your response seems to indicate that the turnaround acceleration or any associated "virtual" gravitational fields is *not* the cause. Correct?

Prof. Nicolai: There is no real paradox here (the formula I gave, and which you can find in any textbook gives an unambiguous answer, given any timelike path in space-time). A good place where you can find a discussion of this and other apparent "paradoxes" of special relativity (all of them due to incorrect reasoning) is in Chapter 1 of the textbook by Bernard Schutz, *A First Course in General Relativity* [2].

Percival: The formula given does indeed enable one to calculate individual proper times, but not proper time differences between the twins. The reply did not answer our questions and we wanted his answer rather than giving our interpretation of Prof. Schutz's 31 page Chapter 1 so we sent Prof. Nicolai basically the same Questionnaire that's shown on the Survey Questionnaire page. (Note: Our view was that while Schutz's Chapter 1 discussed what was *observed*, it didn't discuss how the NPTD accumulated.)

Prof. Nicolai: If you are familiar with Schutz' textbook you will find the answers to the first five questions right there: simply subdivide the world line into intervals, and evaluate the integral for each interval separately to find its contribution to the proper time.

Percival: The NPA is on a sincere quest to find THE generally accepted solution to the Twin Paradox. As such the NPA prefers to get the reply to our specific questions directly from a very well respected physicist and Director of the AEI, namely, you *in your own words* as opposed to our interpreting Prof. Schutz's fine textbook. Hopefully, that will be straightforward as what you wrote above implies that you already know the answers to the first five questions.

Prof. Nicolai: As to your question 6, in my view it precisely creates/adds to the confusion you are trying to clear up, and therefore I will not tick any of the listed items. There is no "physical cause" in the sense of some underlying dynamics, the time delay is merely the result of the *kinematics* of space-time.

Percival: Your statement on question 6 is understood and addresses its first nine items.

Regarding the next two items your answer is clear as far as it goes. However, just as we asked, if you specified "the nature of spacetime", to be a bit more specific, we similarly note that the "kinematics of space-time" is quite general. There are many spacetime theories with very different kinematics of spacetime that give very different physics for the time delay. For example, a (non-aether) preferred frame theory (PFT) might contend that

the "kinematics of spacetime" yield time delays as a function of velocity relative to a preferred frame.

Hence, we are looking for some specificity that is *clearly tied to relativity* (e.g., something that uses a relativistic construct). We are looking for that level of specificity if it is known or an understanding that it is not known. For example, special relativity's time dilation would do it, but above you're avoiding specifying that characteristic.

Finally, when you write the "kinematics of space-time", are you referring to Special Relativity's physical spacetime (as opposed to how each observer observes spacetime) or General Relativity's spacetime or both? We're just trying to make sure that what have been the controversial areas are addressed."

Prof. Nicolai: The formula also directly generalizes to the case when gravitational fields are present, you simply need to replace the Minkowski metric $\eta_{\mu\nu}$ by the appropriate (curved) metric $g_{\mu\nu}$.

Percival: Thanks - we'll just stick to the domain of the original Twin Paradox as enough issues over the decades have been raised on that.

Prof. Nicolai: The correctness of the formula has been confirmed countless times, for instance your GPS would not work without it.

Percival: I don't want to go off on tangents as we are just soliciting your views on the Twin Paradox. However, after that's done, I'll forward some info on the GPS system as an FYI item.

Thanks in advance for your input to this project.

4.3. Analysis

No further response was received from Prof. Nicolai or Prof. Schutz or any others at the AEI despite multiple requests. While Prof. Nicolai's responses were significantly vaguer than Prof. 't Hooft's, they did confirm the basic message. While the basic formula for computing proper times between intervals was given, all questions, even "Yes" or "No" questions, about how the NPTD accumulates were evaded. This seems to confirm that the current mainstream position is that the physics of NPTD accumulation, the "how, when, where" of that accumulation, cannot be described in terms of currently accepted theory. So, to repeat from above, we agree that in the context of currently accepted theory, one cannot tell how the NPTD accumulates and this is a limitation of currently accepted theory.

Similarly, Prof. Nicolai's reluctance to rule out any of a number of mutually exclusive causes echoes Prof. 't Hooft and gets the same response, namely, a definitive answer on how the proper time difference accumulates and the cause of the NPTD is seen to be outside the scope of currently accepted theory.

Prof. Nicolai does say that the NPTD is caused by "the kinematics of spacetime". Again, that answer is fine as far as it goes. However, to tie that very general statement to currently accepted theory requires naming what specific feature of currently accepted theory's spacetime is being referenced. No such specificity was forthcoming. Further, it would seem that currently accepted theory's concept of spacetime lacks the required kinematics-of-spacetime construct, namely, a special physics frame, that is needed to describe/understand NPTD accumulation.

Regarding Prof. Nicolai's assertion that GPS wouldn't work without relativity, see the Open Letter Epilogue and the Report page GPS discussion in section "2) Experiment Results" and attendant references [1].

4.4. Mainstream Response Problem

As mentioned above, a host of solutions have been put forward trying to reconcile the Twin Paradox with currently accepted theory. These solutions encountered insurmountable problems. That may explain why the current mainstream position is that one cannot tell when, where or how the NPTD accumulates. The NPA agrees with the mainstream that current theory cannot tell when, where or how the NPTD accumulates.

However, even this mainstream position that how the NPTD accumulates is unknowable still runs into problems. If, in general, the NPTD accumulates half in the inbound and half in the outbound segment, then the same contradiction that lead to the abandoning of Einstein's initial time dilation claim applies. However, if, in general, the NPTD does not accumulate half in the inbound and half in the outbound segment, then that means the NPTD accumulation is direction dependent and, hence, frame dependent which is contrary to the 1st relativity principle and it, in fact, implies a hierarchy of frames which would necessarily have a special frame at the bottom of the hierarchy (e.g., where clocks run the fastest) as others realized.

Proper time between intervals is absolute. It is not observer dependent. This is true for all clocks' proper times. Hence, the mainstream claim that the NPTD at the midpoint is indeterminate is misguided. What they are really articulating is that Special Relativity predicts that different observers will "observe" different NPTDs at the midpoint (and at other intermediate points). In fact, this even overstates the ability of Special Relativity to predict what will be observed about proper time. It is not correct that observers will *directly* observe different NPTDs. What's really meant is that *given measurements of relative velocity*, observers using Special Relativity will (erroneously) *calculate* different NPTDs. This can be shown by the following.

Let's say that the A frame is the stay-at-home frame and A(1) is the twin at rest in A at the start of the scenario and A(2) is the twin at rest in A at the midpoint of the scenario. Also, B(1) is the traveling twin who goes at constant speed at rest in the B frame for the outbound segment. Further, at the event of B(1) coming to rest again in A, next to A(2), at the midpoint, a light flashes red to mark that event.

In addition, B(1)'s rocket ship has an external clock with a very large display on the side of the rocket ship – similarly, A(2) also has a clock with a very large display. Hence, when ALL observers DIRECTLY observe the midpoint event (marked by the red flash), through a high powered telescope, as opposed to just

doing calculations with measured relative velocities, ALL observers will read what A(2)'s clock reads and what B(1)'s clock reads and, hence, all observers will directly observe the same NPTD (A(2)'s clock reading minus B(1)'s clock reading) for the midpoint. Assuming Special Relativity is being used and, hence, Einstein's convention for synchronizing clocks is being used, then the only way those identical readings of the NPTD can be wrong is if Einstein's convention for synchronizing A's clocks is wrong and if Einstein's convention for synchronizing A's clocks is wrong, then Special Relativity is based on a false assumption, namely, that the speed of light is c in all directions in all inertial frames.

This is one example showing that Special Relativity does not describe what's happening physically. Rather Special Relativity describes the different views that different observers have when they base their worldview on relative velocities. These different views can be quite useful in certain cases. However, Special Relativity does not give the NPTD accurately except for special cases such as the NPTD at the end of a round trip, where, for that special case, Special Relativity happens to agree with Lorentz Relativity.

This further shows that what's needed to properly describe NPTD accumulation is the construct of a special physics frame and the attendant clock retardation as velocity increases with respect to that special frame.

5. Conclusion

Even if one reviews just those papers that claim to reconcile the Twin Paradox with current theory and then one takes an objective, scientific approach, one will conclude that there is much confusion and contradiction on that topic. Hence, it's not surprising that the mainstream position has evolved to saying that how the net proper time difference accumulates cannot be described using currently accepted theory. Furthermore, since the history of science shows that resolving such loose ends often leads to major breakthroughs, this topic should receive serious and open analysis and debate. The NPA Relativity Group concludes that an understanding of the Twin Paradox requires a new/old construct, namely, a special physics frame where velocity with respect to that special frame causes clocks to slow. The reader is urged to review the Twin Paradox website [1] and to sign the Twin Paradox Open Letter, if appropriate.

References

- [1] <http://TwinParadox.net>.
- [2] Bernard Schutz, **A First Course in General Relativity**, 2nd Ed., 410p (Cambridge University Press, 2009).